Using a Web-Based Simulation as a Problem-Based Learning Experience: Perceived and Actual Performance of Undergraduate Public Health Students

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SYNOPSIS

Objectives. This study investigated the use of a Web-based community health simulation as a problem-based learning (PBL) experience for undergraduate students majoring in public health. The study sought to determine whether students who participated in the online simulation achieved differences in academic and attitudinal outcomes compared with students who participated in a traditional PBL exercise.

Methods. Using a nonexperimental comparative design, 21 undergraduate students enrolled in a health-behavior course were each randomly assigned to one of four workgroups. Each workgroup was randomly assigned the semester-long simulation project or the traditional PBL exercise. Survey instruments were used to measure students' attitudes toward the course, their perceptions of the learning community, and perceptions of their own cognitive learning. Content analysis of final essay exams and group reports was used to identify differences in academic outcomes and students' level of conceptual understanding of health-behavior theory.

Results. Findings indicated that students participating in the simulation produced higher mean final exam scores compared with students participating in the traditional PBL ($p=0.03$). Students in the simulation group also outperformed students in the traditional group with respect to their understanding of health-behavior theory ($p=0.04$). Students in the simulation group, however, rated their own level of cognitive learning lower than did students in the traditional group ($p=0.03$).

Conclusions. By bridging time and distance constraints of the traditional classroom setting, an online simulation may be an effective PBL approach for public health students. Recommendations include further research using a larger sample to explore students' perceptions of learning when participating in simulated real-world activities. Additional research focusing on possible differences between actual and perceived learning relative to PBL methods and student workgroup dynamics is also recommended.

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Graduate and undergraduate programs in public health education and health promotion typically include five core competencies: biostatistics, epidemiology, environmental sciences, health services administration, and social and behavioral sciences.[1] Within those competencies lies the field of health education. Health education can be defined as "any combination of learning experiences designed to facilitate voluntary adaptations of behavior conducive to health."[2] This article addresses the professional preparation of public health educators using a problem-based learning (PBL) approach in an undergraduate curriculum.

Over the past 30 years, PBL curricula have attracted interest as an approach to enhance motivation and long-term retention of learned material.[3] Despite PBL's growing use, some educators have argued that professional education programs in public health have not made effective use of PBL in teaching community health concepts to the same degree that medical education has incorporated PBL into the teaching of clinical concepts.[4]

Ideally, PBL-based curricula rely on the presentation of an ill-defined problem in which students arrive at their own solution to the problem as opposed to studying someone else's solution, as in a case study.[5] To be effective, PBL activities must be authentic and present most of the cognitive demands of the real world so that problem-solving and critical thinking are required.[6] Common approaches to the use of PBL include analysis and discussion of static case studies, community-based projects, and service-learning projects. One of the key constraints to these approaches concerns the inability of a student to truly influence the outcome of an effort or to view the resolution of the problem.

In the case of a community-based project, limitations related to the time and resources available to students make it unlikely that the health status of a population can be significantly affected through student intervention when conducted within the time frame of an academic course. It is believed that a realistic scenario can help motivate and enhance the educational experience of students, consistent with constructivist learning theory.

Constructivist learning theory is based on the concept that learners construct their own representation of knowledge, based on their personal prior experiences when presented with problems situated in authentic environments. Additionally, constructivist theory recognizes that learning occurs within a social context in which there is interaction among learners, which influences learning.[7] Given the key tenets of constructivist theory, an effective learning environment is one that places the learner in a real-world environment or a representation of a real-world environment, including the social context and interpersonal interactions with other learners.

A constructivist approach works most effectively when the course content is embedded in the context of new knowledge and skills that will be useful to the student.[8] When learning is useful to the learner, intrinsic motivation will arise from students' desire to understand and construct meaning from the learning process.[9] Given the benefits and limitations of PBL, the question arises as to whether the use of a computer simulation can mitigate the limitations of a real-world experience, while still providing students with an effective constructivist learning experience in the field of public health.

This article describes a study of 21 undergraduate students majoring in public health education at a large public university. The purpose of the study was to determine whether differences exist between students who participated in a semester-long Web-based community health simulation compared with students who participated in a more traditional assignment. Students participating in the traditional assignment were assigned to work in small groups with an actual community to assess community health needs and develop a health-behavior intervention. Students participating in the simulation were presented with a Web-based virtual community, including information resources and analytical tools to assess and intervene during a simulated infectious disease outbreak.

METHODS

Simulation design
An initial prototype of the simulation platform was designed and pilot-tested in 2002 with 28 undergraduate public health students to identify enhancement opportunities and design modifications to the initial approach.[10] The project focused on the use of an Internet-based community simulation in which a tuberculosis (TB) outbreak was presented. Results of the pilot study indicated that students found the simulation to be interesting and potentially motivating. Student feedback included recommendations that collaborative work tools be included, as well as a greater degree of interaction between students and simulation characters.

Based on feedback collected during the pilot test, we completed modifications to provide the following enhancements to the simulation:

- Additional community information was included, such as a listing of schools, descriptions of major

employers, a listing of public health clinic locations and services, and demographic reports.

- An interactive mapping component was added, indicating where community resources and landmarks were located relative to new TB cases.

- Based on weighted responses from the National Health Interview Survey,[11] an online survey builder was developed, allowing students to design and administer a survey and receive realistic results.

- A synchronous communication tool was introduced under the metaphor of a hospital conference room where students could conduct interviews with a virtual TB patient and a physician.

- A dynamic budgeting system was integrated in which the economic costs associated with student activities (e.g., administering a survey and implementing screenings) were calculated and deducted from students' available funds.

Methodology

The study was conducted at a large U.S. public university located in a West Coast suburb during the spring 2004 term. Twenty-one undergraduate students who were enrolled in a single section of a course entitled "Health Behavior" participated in the study. The Health Behavior course was an upper-division undergraduate course required for all students majoring in public health education. The course was designed to introduce students to current health-behavior theory and to provide them an opportunity to apply the theory in a realistic situation. The course was a prerequisite for most health-education courses, and was often completed at the same time as other required courses in epidemiology and biostatistics. Given the objective that students actually apply health-behavior theory,

the traditional course structure was designed to allow students to identify a health problem in a defined community (such as on the university campus) and design and pilot-test a behavioral intervention.

Given the relatively short time frame of an academic semester, together with the lack of health surveillance data, it was impossible to determine whether any behavioral changes actually occurred. A primary objective for the simulation platform was to provide an environment in which time frames were accelerated so that students could monitor both changes to health behaviors and eventually to health-status measures, while having the resources to implement a full-scale intervention in the virtual environment.

We conducted the study using a nonexperimental comparative design by assigning students to one of four small workgroups, with each group randomly assigned to a PBL methodology—either the traditional PBL project or the simulation project. Students were allowed to self-organize into workgroups and assigned numbers (one through four). The workgroup numbers were first assigned to one of the two PBL approaches by assigning the first group numbers to the simulation and then alternating each of the remaining groups between the two approaches. The number of students assigned to each group, as well as attrition within each group, is presented in Table 1. The course instructor informed participating students that data relative to their experiences would be collected on a voluntary basis at the end of the semester, and all students were given the opportunity to change groups, although none did.

We assessed attitudinal measures using the Student Course Experience Questionnaire (SCEQ). The original Course Experience Questionnaire (CEQ) was developed and validated by Wilson et al.[12] as an instrument to measure graduates' experiences with respect

Table 1. Students by assigned workgroups

Item	Group 1 traditional	Group 2 simulation	Group 3 traditional	Group 4 simulation
Students assigned to groups	5	5	5	6
Students who completed the course	3	5	5	6
Students who responded to the survey	3	4	5	5
Student attrition				
Dropped the course	1	0	0	0
Accepted an incomplete	1	0	0	0
Excluded from group by other members but completed course	0	1	0	1
Mean grade point average[a]	2.38	2.92	3.16	2.70
Mean cumulative units	106	100	92	84

[a]Collected from student academic records

to a degree course. The SCEQ, modified by Ginns and Prossner,[13] included specific revisions designed to address the experiences of current students rather than graduates. The original CEQ included six sub-scales that measured good teaching, clear goals and standards, appropriate assessment, appropriate work-load, emphasis on independence, and the reported acquisition of transferable skills. Construct validity of the CEQ was determined by Broomfield and Bligh[14] using principle components analysis in a study of 189 medical students.[15]

The SCEQ included a Learning Community Sub-scale (LCS), which we utilized to control for group dynamics when evaluating academic performance between groups. Perceived cognitive learning was measured using a self-reported cognitive learning instrument in which students were asked to rate their level of learning on a 0 to 9 scale.[16]

Academic achievement in the health-behavior course was measured using a case study-based exam, which had been used in the course in prior semesters. The case study consisted of actual demographic, socioeconomic, and health statistics data for Bergen County, New Jersey. Students were provided with 11 essay questions, based on the case study and specifically written by the instructor for the course, asking about the steps involved in assessing a community health need, and the development and evaluation of a behavioral intervention. Students' grade point averages (GPAs) and completed units earned were appended to the exam scores to support analysis of covariance (ANCOVA). Prior to being graded, exams were blinded as to students' identities and group membership.

After grading was completed, we analyzed exam scores and attitudinal ratings between the two groups of students using ANCOVA procedures with covariance controls for variables such as student GPA, number of units taken (under the assumption that students with more units might have more academic experience and better study skills), and the perceived strength of each student's learning community. We additionally collected qualitative data through a focus group held with students upon the conclusion of the course and by specifically asking students for their feedback on the anonymous surveys.

RESULTS

Assessing self-reported cognitive learning

Self-reported cognitive learning was measured through use of a single-item instrument in which the follow-ing question was asked: "On a scale of 0 to 9, how much did you learn in this class, with 0 meaning you learned nothing and 9 meaning you learned more than in any other class you've had?" Response values ranged from 5.0 to 9.0 with a mean value of 7.38 and a median of 7.5.

The LCS instrument measured students' attitudes as to the effectiveness of students' interactions with fellow group members and the instructor. To control for dif-ferences in small-group dynamics, we tested LCS scores as a covariate to perceived learning and found the LCS score to be a statistically significant covariate ($p=0.005$). Controlling for the LCS score, students participating in the traditional project reported a higher adjusted mean cognitive learning score of 7.9 compared with students who participated in the simulation project, who had a lower adjusted mean score of 6.9 ($p=0.03$). These findings are presented in Table 2.

Academic performance

Student assessment at the end of the semester was con-ducted using a case study-based final exam. Mean exam scores were compared for each student workgroup, controlling for students' GPAs as a covariate. Using this approach, students participating in the traditional project produced a lower unadjusted mean score of 73.1% compared with 85.5% for students participating in the simulation project ($p=0.03$).

To identify group differences related to specific competencies, the exam was broken down into four components consisting of (1) community-health needs assessment, (2) intervention planning, (3) evaluation, and (4) health-behavior theory integration. Control-ling for GPA, higher exam scores were found among students participating in the simulation in the areas of needs assessment ($p=0.05$) and intervention planning ($p=0.03$), while scores for the evaluation ($p=0.85$) and theory integration competencies ($p=0.12$) were not significantly different between the two groups. Mean scores by component are presented in Table 3.

Table 2. Differences in perceived cognitive learning

Item	Traditional group	Simulation group	DF	F-statistic	P-value
Mean self-reported cognitive learning	7.90	6.90	1	5.47	0.03

DF = degree of freedom

Table 3. Unadjusted final exam scores by PBL approach controlling for GPA (*n*=18)

	PBL method		DF	F-statistic	P-value
	Traditional (percent)	Simulation (percent)			
Final exam scores					
Needs assessment	84.0	92.0	1	4.19	0.05
Intervention planning	65.5	84.3	1	5.69	0.03
Evaluation	67.0	63.1	1	0.04	0.85
Theory integration	65.2	85.1	1	2.68	0.12
Total score	73.1	85.5	1	5.53	0.03

PBL = problem-based learning

GPA = grade point average

DF = degree of freedom

Additionally, a comparison was made to students' midterm exam scores to determine whether differences existed earlier in the semester prior to completion of the projects. Controlling for GPA, no difference in scores existed between students participating in the simulation vs. the traditional project ($p=0.33$).

Student feedback
Regardless of whether they participated in the simulation or the traditional project, students in all groups most frequently cited the PBL project as being the best part of the course. Students in the simulation groups also cited the effectiveness of the instructor, the real-world aspect of the simulation PBL, and positive student interactions. Students in the traditional groups tended to cite the classroom discussion as the aspect they liked most about the class. Students participating in the simulation also referred to the convenience of working in an online environment and the sense of being a practicing professional and having all of the same tools available in the virtual environment.

We found that interpersonal communication issues and differences in work styles were key issues for all student workgroups, regardless of modality. When simulation-mode students were asked, "How could this course be improved?" the most frequent responses related to a better approach for managing student group work, followed by clearer communication of expectations and by individualized grades for students working in workgroups. Typical responses included statements such as ". . . it is hard to work with people who are not as motivated as you are to finish a project. . . . some people do not put in as much [effort] as others do."

Issues relating to problems of group dynamics were also reported by students in the traditional project groups. Overall, one-third of respondents suggested that a different approach to group work would be an improvement to the course.

Scores from the SCEQ varied across workgroups for each of the subscales. Although significant differences were found for a number of the subscales among workgroups, no clear pattern existed between students participating in the simulation and students participating in the traditional project.

DISCUSSION
Students who participated in the simulation performed significantly better on the final exam, particularly in the areas of community-health needs assessment and intervention planning. Results suggest that the community simulation may have provided an effective learning environment in which students' skills could be applied within the context of a real-world problem. We hypothesize that students participating in the real-world project were likely limited in their efforts by the lack of access to community health-status information, which was readily available to students working with the simulation. Additionally, students in the traditional PBL project groups were never able to view the health outcomes associated with their intervention strategies, while students using the simulation were able to evaluate the results of their strategies and determine which elements were effective and which were not, and to make course corrections when necessary. The lack of differences among student groups with respect to midterm exam scores supports the possibility that the differences were, in fact, due to the PBL projects, as the majority of the PBL work occurred later in the term, after the midterm exam.

A counterintuitive finding in this study relates to the seemingly inverse relationship between perceived learning and actual academic performance. Overall,

student workgroups participating in the simulation projects reported lower mean perceived cognitive learning scores than those participating in the traditional projects.

The self-reported cognitive learning scores also provide an interesting juxtaposition to the final exam scores. The traditional project groups reported the highest perceived cognitive learning score but had the lowest mean final exam score, while a simulation group, which returned the lowest self-reported cognitive learning score, was tied for the highest mean final exam score. The seemingly inverse relationship between cognitive learning and actual academic performance suggests that the group dynamics and social experiences related to the learning environment may play an important role in students' perceptions of their own achievement. This concept is also supported by a positive association between students' self-reported cognitive learning and their assessment of the learning community, as measured by the LCS. Given the results, differences in perceived learning may be due to the PBL approach. One possible explanation is that the simulation provided a richer environment with respect to available data and may have produced a degree of information overload among students and, hence, lower self-reported learning.

The implications of constructivist learning theory may also help to explain this seemingly inverse relationship in students who participated in the simulation. Given the simulation's unfamiliar learning objectives and methodologies, students may have perceived their learning as lower due to discomfort related to lack of familiarity. In contrast, the more familiar learning environment (i.e., the traditional project) may have been experienced as more comfortable, resulting in a perception of enhanced learning.

A related finding was the importance of the learning community dynamics as demonstrated by the correlation between self-reported cognitive learning and the LCS score. Given the dynamics of any challenging PBL environment, it would seem intuitive that students' reliance upon each other becomes an increasingly important aspect of the learning experience, particularly when students are presented a challenging problem to be solved, requiring a coordinated team effort.

CONCLUSIONS

Our assessment of academic performance suggests that use of a computer simulation in the teaching of community health concepts may be effective, given the limitations of a traditional real-world assignment. Students participating in the simulation produced higher exam scores in the areas of needs assessment and intervention planning. The study revealed a possible difference between actual and perceived learning, which is worthy of further research. Given our data collection constraints, further research in which additional student-level data are collected may help to quantify differences between what students believe they have learned and what they actually have learned. Finally, the relationship between students' perceptions of the strength of their learning community and perceptions of their degree of cognitive learning serves to highlight the importance of a learning environment in which teamwork and group dynamics are facilitated.

Informal student feedback also suggested that the convenience of being able to participate in a challenging collaborative effort asynchronously while adapting their efforts to their other academic, professional, and personal obligations was a positive factor. The ability to facilitate collaborative group work around a virtual, yet realistic problem may provide an important means to offer constructivist public health training opportunities in a global environment by transcending constraints related to time and space.

Limitations

The study was limited by the size and distribution of the sample. Because only one section of the course was taught each semester, the comparison of two student groups in two sections of the course was not possible. Instead, one section of the course in the spring 2004 semester was divided into two groups, with half of the students forming two workgroups and completing the traditional class project, while the other half of the students formed two workgroups and completed the simulation. Given that a convenience sample was used, the results cannot be readily generalized to all students in the public health education major or across universities.

Additionally, academic outcomes were assessed using students' performance in the health-behavior course. The study design did not address how use of the simulation might have affected student performance in subsequent public health courses.

Thirdly, an odd number of students in a class, combined with students who dropped the course, resulted in uneven numbers in some workgroups. Although anecdotal evidence suggests that varying the size of workgroups may affect students' efficiency, it is believed that workgroups that were sized to within one student member of one another would be unlikely to have a significantly different experience solely based on the group size.

Recommendations

Because of the inconsistencies found between perceived learning and academic performance, we suggest further research to better understand the relationship between students' perceptions of learning and their learning environment, particularly with respect to small-group dynamics. Based on the relationship between learning community scores and actual and perceived performance, investigation is also merited into the possible use of team-building and technology-orientation exercises at the outset of the PBL experience as a way of strengthening group cohesion. Team building may also serve to better equip students with the skills necessary to work together through a challenging academic experience.[17]

Further research should utilize a larger sample comparing entire classes to avoid commingling students participating in different modalities. Additionally, a longitudinal study in which students are followed throughout their remaining courses may help provide a big-picture view of how the simulation affects performance in subsequent courses. At this time, we are in the process of undertaking a more comprehensive study in which larger groups of students are provided a team-building exercise prior to beginning either a simulation or traditional health-behavior PBL project. Students' performance in the health-behavior course and other subsequent public health courses will then be assessed to better understand the short- and long-term relationship between PBL methods and academic performance.

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